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Original Article

THE SYNOPTIC VIEW OF USING PHOTOVOLTAIC-MICROBIAL FUEL CELL (PV-MFC) RENEWABLE HYBRID SYSTEM TO ADDRESS MUNICIPAL ELECTRICITY NEEDS: CASE STUDY CITY OF UMHLATHUZE

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ABSTRACT

Municipalities are often faced with the challenge of balancing their demand for electricity from the utility and the cost of securing adequate electricity from the same. This, together with poor planning, has led to municipalities ordering more electricity from the utility than the actual energy required and consumed on a month-to-month basis, at the expense of its citizenry because of the additional charges incurred by the municipality in this process. This paper proposes a lasting solution which involves renewable sources that the municipality can easily attain to address challenges highlighted by the problem statement and the research questions. The paper highlights the approach of acquiring electricity from renewable energy sources and the impact that feasibility studies as part of planning and the implementation of photovoltaic-microbial fuel cell (PV-MFC) hybrid system can have on municipal electricity status and the municipality's ability to provide effective services that support economic growth and improved quality of life within its jurisdiction.

KEYWORDS: Municipality, Electricity Status, Renewable Energy & PV-MFC Hybrid System

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1. INTRODUCTION

This paper provides an overview of the importance of innovative thinking in the exploration of renewable energy as a long lasting solution to the present day challenges faced by the country with regards to energy status at a municipal level. Energy sustainability can be implemented and achieved to improve reliability of municipal treatment facilities at the city of uMhlathuze through the use of a hybrid system consisting of microbial fuel cell (MFC) and photovoltaic cell (PVC) technology. An approach of implementing the feasibility of this technology as a means of generating power at the city of uMhlathuze is discussed by highlighting the problem statement and research questions that must be addressed during planning. This paper highlights the gaps caused by poor municipal infrastructure, lack of leadership and committed pursuit by government of renewable energy generation, and decreasing security of energy supply at municipal level. These factors negatively affect the economic activities taking place within the municipal jurisdiction and reduces the quality of life of the general citizens. Furthermore, the paper highlights the benefits of local municipalities generating their own power from readily available and easy to process renewable sources using hybrid renewable energy systems such as a PV-MFC hybrid system in order to be able to deliver suitable services to the people and the trading enterprises operating within the care of the municipality.

uMhlathuze municipality is, according to the Constitution of the land, responsible for implementing

government mandates of providing meaningful service to the citizens of Richards Bay. The City of uMhlathuze is used as a case study in this paper. In so doing, this paper offers a brief background to the subject matter, including the problem statement and the why and how of the study in order to exhibit the significance of the research. Outlined is the aim of conducting a feasibility study as an integral part of planning that when the corresponding purposes are pursued with great strides, the problem statement will be addressed, the aims and objectives of the research satisfied and the research questions answered.

2. BACKGROUND

South Africa's chronic energy crisis is having dire consequences for the economy and quality of life of its citizens. Industrial and commercial trading enterprises can see that the government integrated energy resource plan (IERP) is useless in forecasting energy requirements and possible strategies of addressing energy shortages (security of supply) and supply challenges. Supply challenges emanate from population growth and exponential demand for energy. Countries should attempt to be energy self-sufficient (Hinrichs and Kleinbach, 2002), which they can do through harvesting energy from renewable sources by using modern technologies that are aimed at optimising the harvesting of energy efficiently from renewable sources (Sørensen, 1979). Kohler (2013) states that the newly developed integrated energy resource plan (IERP) sets out South Africa's plan for energy (electricity) generation and supply over a 20-year period to secure improved security of supply and energy efficiency. However, the challenges faced by considering potential generation modes in the country is that technical specifications of identified energy systems or projects are evaluated and recommended without always reviewing whether they are affordable.

Joffe (2008) states that the challenges facing South Africa's electricity supply industry are a result of policy and regulatory uncertainty over the previous decades due to the lack of open competition. In this context, Eskom (the government's biggest and only trusted energy utility or enterprise) decided to build two new gigantic coal-fired power plants that are unsustainable in the near future due to depleting coal (unsustainable resource) and the forever increasing costs of using coal to generate electricity. Joffe (2008) further states that South Africa requires massive new financial investments to enhance the country's generating capacity to satisfy growing energy demand, but a lack of planning has resulted in government re-iterating its existing energy strategy of coal-fired power stations as baseload power stations.

Joffe (2008) states that it is essential that the economy facilitates and sustains investment and economic growth in order to provide access to electricity for all. Del Mar Martinez Diaz (2017) states that implementation of innovative means in the renewable energy sector can eradicate energy shortages and undesired related consequences. Joffe (2008) encouraged the government and Eskom to make an urgent transition towards more diverse sources of supply because diversifying the energy mix is important in building confidence in electricity supply, securing energy capacity, addressing challenges of climate change, and attracting new funding and partnerships that secure technology and skills. In addition to diversification, Joffe (2008) points out that energy efficiency is a major driver that shapes the environment in which the existing and new infrastructure delivers electricity. According to Khanal (2008), 722 quadrillion BTUs of energy will be required by year 2030. Sinha (2008) states that the global primary energy consumption of about 1200 EJ/year that is forecast for 2050 can be reduced to 800 EJ/year to 1000 EJ/year by 2050 by means of the incorporation of energy efficiency devices. Sinha (2008) further states that, although 80% of present primary energy requirements globally are met through fossil-based fuel (coal), fossil-based energy consumption must be reduced and limited to 300 EJ/year by 2050.

Modise and Mahota (2009) from the Department of Energy (DoE) of South Africa stated that the procurement

target for energy from renewable sources by 2030 is 18.2 GW. According to Ferry and Giljova (2015), South Africa has a high potential for producing lucrative and affordable energy from renewable energy exploration to satisfy the required energy target by 2030 through the installation of modern renewable energy technology. Unfortunately, the target stated by Modise and Mahota (2009) (18.2 GW) is additional required energy and does not account for the replacement of the electricity produced from coal-fired stations by generation from renewable sources. The long-term energy status of the country will continue to be uncertain unless there is a commitment from government to explore renewable energy using modern renewable energy technology which involves conducting comprehensive feasibility studies.

Hasley and Schubert (2017) state that South Africa is a developing country faced with fast depleting fossil-fuel reserves and rising costs, so the South African government should encourage public-private partnership and local municipalities to generate renewable based energy and support municipalities by investing on reconditioning their infrastructure to acceptable conditions to support renewable energy generation and economic growth at municipal level.

The 2008 March issue of the South African Energy Statistics report states that the South African economy is dependent on energy resources because almost all economic activities of the country are one way or the other directly or indirectly linked to energy consumption. Barker (2008) concurs and states that currently the South African economy is heavily reliant on security of supply from the national grid, however the South African economy suffers from lack of power and lack of reliable infrastructure capacity to cater for current and future projected economic investments and activities. Barker (2008) states that lack of power capacity reduces the ability to drive energy dependent economic activity demands. This then affects the ability of South Africa to trade with the rest of the world as investors to South Africa are apprehensive and are starting to lose confidence in the country's energy health and recovery programme. The 2017 report by Deloitte takes a synoptic view of electricity consumption and pricing in South Africa, confirming that economic activities in South Africa are energy intensive, as they have been historically, with only small improvements over the years.

The 2015 Financial Mail publication on South Africa's energy crisis, expresses that the South African government is lagging behind in resolving its energy related problems regarding generation and security of supply, and that the government is currently playing catch-up in order to build sufficient energy capacity to meet the current and future demands so as to support the economic well-being of the country. The Creamer Media Water Report (2012) states that South Africa is increasingly at risk of becoming a high infrastructure and energy failure rate country, due to the lack of government spending (intervention) on infrastructure, lack of support for renewable-energy based initiatives, lack of infrastructure capacity to cater for increased demand, and lack of effective implementation of maintenance programs that seek to restore existing infrastructure to acceptable condition and good levels of performance.

Carter-Jenkins (2008) points out that wastewater treatment plants at municipal level are energy intensive processes that require significant implementation of energy efficient treatment processes to promote and improve sustainability, reduced energy consumption and reduce the costs of operating wastewater treatment facilities. The authors propose that municipalities must be empowered to use resources that are readily available at their disposal, such as biomass from municipal sewage and other types of renewable energy sources to generate electricity to power their wastewater treatment plants.

Municipalities in South Africa are the major custodians of the majority of state infrastructure assets. Constitutionally municipalities are mandated to provide delivery of services to communities within their jurisdiction in a

sustainable and affordable manner, within the allocated budgets. However, the findings of the 2007 audit study conducted by the Council for Science and Industrial Research (CSIR) on the condition of infrastructure at municipalities indicates that the infrastructure at municipal level is in a poor condition and that there is lack of asset and maintenance information on this infrastructure. For this reason, infrastructure failure related to municipal operations is common, often resulting in community unrest (protests), environmental pollution, accumulation of exorbitant energy and financial bills, and heightened demand for capital 'financial investment' injection.

Xia and Zhang (2015) state that when there is an unbalanced electricity grid, two options exist in attempting to restore stability; the first is to increase the supply by building new infrastructure or electricity generating plants, and the second is to decrease energy demand by improving energy efficiency through encouraging consumers to switch off appliances, or to switch to renewable energy sources. Xia and Zhang (2015) states that whatever option is opted for, it is important to consider time frames, initial capital investment, maintenance and operations costs, as well as potential energy savings. Load-shedding is the least popular method of encouraging a decrease in demand for electricity, as load-shedding dampens investor confidence and has a negative effect on economic growth activities.

Considering the above, and that the uncertainty of coal-based generation has been highlighted time and time again by various authors, the South African government mandated Eskom to construct two new fossil fuel (coal) giant power stations that at the time of reporting by Chris Yelland (2016) had already cost South Africans over R300 billion but were still uncompleted.

Baker and Philips (2019) state that South Africa's electricity sector faces significant government-leadership based and economic challenges, whereby energy politics remains unresponsive to technological change, economic stress and to the transformation of conventional electricity utility models based on centralised system of transmission, generation and distribution to decentralised deployment of renewable energy based generation.

Taking into consideration the effects of poor planning and management of the construction of the new power plants, the opportunity costs of not embarking on full pursuit of the exploration of renewable projects, and the impact of the prevalence of corruption in South Africa, energy costs are estimated to increase, making energy unaffordable for industries, businesses and the general citizenry. In response to the views of Xia and Zhang (2015), and taking into consideration prices to process coal to electricity and the uncertainties of the future of coal reserves, this paper highlights that conducting detailed feasibility studies on the use of renewable energy sources together with identified hybrid technologies in order to establish customised models for the energy sector of the country to establish reliable, sustainable and affordable electricity supply for the country based at municipal levels that is without harmful effects to the environment is of paramount importance and must be conducted with great commitment.

In an attempt to focus on the impact that an PV-MFC hybrid system would have in the uMhlathuze municipality, planning the implementation of a PV-MFC hybrid renewable system through the use of the feasibility study must comprehensively take into account the history of the climate in Richards Bay, the type of effluent discharged, capacity of the wastewater treatment plant (which in this study is the water treatment plant and water pump station), energy bills, condition of infrastructure of the treatment plant, the pre-treatment processes required for the system, and performances of each plant especially in terms of energy efficiency and the effectiveness of policy reviews.

The task that this paper firstly submits is that the municipality's monthly energy consumptions must be

established, the challenges encountered by the municipality in honouring obligations in terms of energy conservation and management and reduction of energy bills, and in maintaining acceptable good infrastructure conditions. A number of studies by various researchers regarding the various technologies focussing on renewable energy have been conducted, but the feasibility of developing technologies in terms of available natural resources (location or site characteristic properties of natural renewable resources) at the disposal of municipalities has not been adequately covered in South African research. Thus, considering the gaps and challenges identified, this study recommends implementation of an PV-MFC hybrid system with the objective of encouraging customized energy generation and enhancement of energy sustainability at uMhlathuze local municipality.

Therefore, the study must focus on assessment and evaluation of the efficiency of wastewater infrastructure under the responsibility of the Infrastructure Services Department of the municipality because this department is responsible for keeping the water and wastewater infrastructure operational and for identifying and proposing ventures into new innovation around infrastructure development (they are the custodians of infrastructure related initiatives and sustainability), and the Electricity Services Department because this department is responsible for energy management, energy audits, distribution of electricity from the national grid and collecting corresponding revenue, and could conduct other energy related initiatives such as electricity generation using natural resources.

In a nutshell, this paper has been motivated by the shortage of electricity supply that has resulted in load-shedding and a call by government for partnership agreements related to alternative affordable sources of energy. This paper highlights a method or approach that the South African government can pursue to achieve affordable and sustainable 'renewable energy based' means of generation. The use of municipalities to generate their own electricity and reduce bills accordingly that is aimed at powering the treatment plant so that citizens within the jurisdiction can have access to reliable energy and efficient delivery of services.

2.1 Problem Statement

Karekezi et al. (2004) state that the problem faced by most African countries is not the increase in energy consumption per se, but the confident access to clean energy supply preferably through energy efficient methods. The African continent has abundant renewable energy sources that can support the exponential growth in energy demand. Karekezi et al. (2004) (citing Zhou, 2003) state that generation using renewable energy research has not received enough attention from governments on the African continent, in terms of committing funds and conducting feasibility investigations and pilot implementations of renewable-based generation at an up-scaled size. This has consequently resulted in renewable technology remaining unproven for municipal buy-in. This has perpetuated the unaffordable energy supply paradigms that have led to current serious challenges. In support of the above view, Onyekwelu and Akindeke (2006) state that the economies of various developing countries are dominated by a few multinational corporations that are often profit oriented and that African governments tend to be loyal to them at the expense of the poor citizens.

The Delloite (2017) report indicates that the energy consumption at treatment plants is highly dependent on the modernisation of households to conserve water and electricity, the condition and performance of the municipal water and wastewater infrastructure system, the ingress of unsolicited substances that resultantly dictate the type of treatment required and any additional processes required in separating and/or treating unwelcomed substances, and the degree to which the technology used at the treatment plant is energy efficient and conservation orientated. Due to the changing operational conditions based on various factors such as infrastructure degradation, and new economic activities from new

industries and commercial institutions, frequent review of treatment processes and programs directed towards the implementation of rehabilitation of infrastructure must be pursued in order to improve energy consumption, improve the quality of municipal biomass (sewerage) and effective performance and efficiency of the municipal infrastructure i.e. the treatment plants.

Winkler and Marquard (2009) state that the South African industrial electricity efficiency is an ongoing concern as it contributes far less to the South African GDP and is considerably lower than the global average. In order to address this challenge, Kohler (2013 citing Inglesi-Lotz and Blignanat, 2011), suggests that South Africa's electricity supply shortages require a nation-wide demand-side management programme that will see energy efficiency improve.

Maistry and McKay (2016) state that research institutions are faced with increasing pressure to come up with effective management technologies that manage electricity demand and costs reduction caused by energy inefficiencies and resource uncertainty. Historically, a lot of facilities and equipment in South Africa were built when energy optimisation was unimportant, the challenges of managing electricity consumption from the national grid were insignificant, and the difficulties of sorting and engaging sustainable practices that seek to create energy-efficient technologies were not considered important. Thus, there was no urgency for financial investments in technologies that tapped into multi-renewable energy sources. For this reason, the CSIR report (Wall, 2010) reflects that energy-efficient devices are not common in conventional treatment plants in South Africa. Based on views by Saini (2007), well-motivated personnel are best at developing and implementing energy efficiency policies that are pragmatic and benefit cost reduction, enable savings on utility bills, improve ways at which facilities and equipment are operated and maintained, and play a major role to having energy efficient systems.

Municipal institutions around the country owe Eskom tens of billions of rands, leading to heavy national deficits in terms of energy and South African rands, lack of power capacity and inability of the country to provide reliable energy supply and proper service delivery at municipal levels (Barker, 2008). High national debt leads to downgrading of the country's credit rating which has a negative impact on South Africa's ability to acquire funds (borrowing power) to implement hybrid renewable energy system (HRES) projects (Smith and Lunsche, 2008). The danger is that investors will then take their monies and skills elsewhere (Mthombeni, 2008).

Lunsche (2008) states that government cannot afford to repeatedly find itself consistently underestimating energy demands as it is currently doing. Government must invest in other forms of energy sources to fast-track security of energy supply and also counteract the increasing effects (costs) of generating electricity from the fast-depleting and now more expensive fossil based fuels (coal), as lower grade coal is increasingly being encountered.

Cherp and Jewell (2011) state that the three distinct perspectives of energy security are: sovereignty, robustness and resilience. Trollip et al. (2014) add that energy security is complex, requiring a multi-disciplinary approach that analyses resilience and addresses integrity challenges.

Trollip et al. (2014) state that the myopic focus in solving energy resource challenges facing South Africa's energy system has created a monumental backlog in infrastructure development and investment paralysis, shortages in bulk electricity supply, a growing backlog and ongoing deterioration of electricity redistribution infrastructure, poor household energy security, discontinuities in coal supply, absence of a credible liquid fuels policy and comparatively low crude oil stocks.

Trollip et al. (2014) advocate for a broad conceptualisation of energy security based on the World Energy Council's (WEC's) tenets of accessibility, availability and acceptability, supplementing the Department of Energy's (DoE's) focus of ensuring diverse energy resources in sustainable quantities and at affordable prices being made available.

Ketelhodt and Wocke (2008) state that, though small and medium enterprises (SMEs) in South Africa are regarded as the future engines of growth for the South African economy, SMEs are one of the most vulnerable sectors to unstable energy environment and policy shifts. Since SMEs are generally incapable or lack the resources necessary to invest in alternative sources of energy themselves, and are generally operated, located, and served by municipalities, a reliable, abundant, low priced source of electricity at this level is critical. The lack of availability of low priced primary energy sources hinders or constrain the future growth of the South African economy as SMEs are left with bleak future prospects.

The efficient use of energy, especially at municipal level, is an important concept that needs to be embraced to support economic growth activities. Pakenas (1995) states that though wastewater treatment plants consume large amounts of energy, the same plants have the capacity to produce large amounts of biogas (a combination of methane and carbon dioxide) from sewage sludge. In support, Hampton (2017) states that the process using harvested natural reserves such as from human waste for the purpose of generating electricity, together with the use of appropriate technologies that produce and use a mixture of methane, carbon dioxide and traces of other gases, must be pursued to power the pumping equipment in treatment plants. Onyekwelu and Akindele (2006) state that the use of animal or human residue is a cheap and viable alternative to national grid power.

Wong (2011) states that wastewater treatment plants present untapped sources of renewable energy, and the use of bio-solids can generate biogas that contains up to 70 % methane which can be used to generate electricity. Pirnie (2005) states that over and above having local sources of energy, municipalities must undertake continuous sub-metering of major pieces of equipment in wastewater treatment facilities in order to identify energy-saving opportunities by capturing diurnal variations in electric energy demand so that reviews of equipment replacement or modification and methods of operations are made.

Soltes et al. (1982) state that technology and technology improvement is vital for economies of scale in terms of process efficiencies and investment. Energy output, according to Soltes et al. (1982) is the amount of electricity generated, and that before generation, the fixed power requirements must be determined and viable technological options of producing electricity from municipal waste and other readily available resources must be identified and be aligned with the purpose of powering some of the identified municipal equipment.

The most crucial step that municipalities must undertake before implementation of renewable energy projects, is an energy audit of the treatment plant (Hallet et al., 2012). This involves the comprehensive collection of data in order to:

- Evaluate energy consumption and efficiency through an on-site survey to identify maintenance and/or operational needs and deficient equipment;
- Analyse energy consumption information in order to understand energy usage patterns and develop an energy baseline; and

- Estimate energy and cost savings with emphasis on incorporating low or no-cost measures such as energy saving devices, or the redesign and reconfiguration of the plant equipment and/or processes (Hallet et al., 2012).

King (2004) states that energy comes in many forms, and can be converted from one form to another. Gikas and Tsoutsos (2013) state that the most common process of harvesting energy in municipal wastewater is to use activated sludge treatment. The aeration process is by far the greatest energy consuming process in a conventional activated sludge wastewater treatment plant, with the aeration tank consuming up to 55% of the energy (Gikas and Tsoutsos, 2013; Badruzzaman et al., 2015). For energy usage to reduce, consideration and introduction of energy efficient devices must be used together with replacing or improving core equipment with energy efficient (advanced) automated devices and technologies (Badruzzaman et al., 2015).

The location of the city of uMhlathuze and the need to address energy consumption challenges of adequately operating pumping installations at the treatment plant, and energy from available biomass and abundance of sunlight (solar energy) must be investigated to examine the prospects of implementing a PV-MFC hybrid system to power the municipal treatment plant at affordable rates that subsequently benefit SMEs and the citizenry. The benefits of employing a hybrid system rather than individual mono-systems such as MFC systems or PV cells systems have been highlighted and examined by various researchers, endorsing the feasibility of a hybrid system at a municipality's best aid with its functions of effectively delivering services to customers and citizens within its jurisdiction.

In order to propose the best-suited hybrid system, the quantity and quality of sludge required to achieve optimum efficiencies using microbial fuel cell technique must be examined together with the abundance of sunlight based on the topographical location of uMhlathuze municipality. Establishing these factors together with needed electricity, the type and size of the hybrid system can easily be identified and formulated from the different MFC system types and PV system types in the market that best suit the South African market. In satisfying the objectives of this research of using solar energy source and biomass to co-generate, this paper aims at assisting the municipality to decide on which renewable energy configuration and procurement route to undertake. Financial models for financing this renewable energy project must be evaluated and outlined for purposes of evaluating the viability of the HRES and its payback under clearly defined, well-understood and government supported legal rules.

The City of uMhlathuze municipality has been procuring services of a service provider to operate and maintain the water and wastewater treatment facilities in order to ensure effective performance in the delivery of services and acceptable infrastructure conditions. One of the measures that should be a reliable indicator of the effectiveness of the maintenance program in place and the infrastructure condition at the wastewater treatment plants is the availability, accuracy and reliability of performance data of each treatment plant and the records of the frequencies of inspections and maintenance work conducted on the infrastructure. Thus, the impact of infrastructure conditions and assesses the corresponding energy bills is crucial. Strategies or known initiatives employed by the municipality in alleviating energy demands at treatment plants such as incorporation of energy saving devices or components and sourcing alternative energy supplies to power treatment plants (if any) were noted. The purpose of the above examination is to capture the true reflection of the impact of incorporating renewable energy supply technologies in these plants through conducting a detailed feasibility study. Liff (2011) highlights that the biggest challenges that managers in government institutions face is the lack of support from their superiors because they are not given the autonomy to devise new ways to solve problems, and encounter red-tape in trying to get approval for spending of funds for initiatives deem fit by the manager. In addition,

the government's budget cycle inhibits the manager from acting immediately, and inter-departmental or inter-disciplinary challenges tend to limit the formation of an integrated high performing team. Therefore, some managers take the path of least resistance.

This research paper thus highlights that the extent to which exploring alternative renewable sources encourages sustainability of treatment plants and credible delivery of services, determine the feasibility of PV-MFC hybrid technology at the municipal level and how the hybrid system positively impacts the energy demand, reduction of energy bills and reduce negative impact on the environment.

3. Methodology

3.1 Motivation for the Study

This paper examined the leadership challenges faced by the country with regards to energy shortages that disrupt municipal functions as mandated by chapter 2 of the Constitution, resulting in undesired consequences that negatively affect the socio-economic portfolio of the country. Municipalities at the time of writing this paper secure energy mainly from fossil-fuel (coal) power plants, and studies by various authors indicate that the vulnerability of the country's national grid emanates from the dynamic behaviour of coal reserves, poor planning and leadership in forecasting and implementing strategies that resolve energy challenges and poor infrastructure conditions.

In order to salvage the country from the irreversible catastrophic consequences of unsustainable and unreliable security of supply, this paper proposes the implementation of a hybrid renewable energy (HRES) project using municipal resources such human resources, finances and other government developed tools like public-private partnerships (PPP) to fast-track and enable the implementation of renewable energy generation. The view expressed in this paper is that decentralisation of generation and the use of municipalities as energy hubs to pursue renewable energy generation projects need to be pursued. The city of uMhlathuze is used as a case study for government to pursue this initiative.

The call by the South African government for public-private partnership is a step in the right direction, however the guidelines as to how such partnerships can be managed without disadvantaging citizens is of paramount importance. For successful coherent partnership of government with services providers (research institutions, professional private companies and person(s), experts in the energy sector) through fair use of procurement tools and processes stipulated in the public-private partnership (PPP) guidelines and other supply chain management (SCM) policies must be put in place to enable municipal procurement to be conducted and handled with care, with zero objections or perceptions of corrupt practices.

3.2 Aim of the Study

The aim of the study is to establish a means for determining the feasibility of PV-MFC hybrid system at uMhlathuze municipality to power the municipal wastewater treatment plant and how energy management and reduction of energy bills can be achieved in powering wastewater treatment plants. Gaps with regards to energy supply policies (legislation and governance) and initiatives (funding and implementation of energy efficacy strategies) must be identified and defined together with shortfalls of strategies in place of reducing energy wastage and infrastructure challenges that have negative effects on energy demand. A relationship is reflected by various authors of how infrastructure condition impacts energy demand, and how employing alternative renewable energy sources using HRES such as PV-MFC hybrid system reduces energy bills from the national grid (energy conservation), resulting in savings in the short-to-medium term that can be used

elsewhere and improve the sustainability of energy supply. Thus, this paper reflects the strengths of implementing PV-MFC hybrid systems in powering wastewater treatment plant.

3.3 Objectives of the Study

- To evaluate the current infrastructure conditions at the treatment plant and how energy consumption is influenced by this.
- Identify gaps that worsen energy demand or increase energy bills (include energy wastage).
- Identify gaps of governance on energy management and energy supply by municipality to treatment plants. Consider national stipulation encouraging municipalities and other institutions in implementing technologies that aid harvesting renewable energy to power their own facilities.
- Establish the link or relationship of the country's energy status to economic activities, quality of life of citizens, effective delivery of services to the benefit of immediately implementing HRES projects that improve energy affordability, energy reliability and sustainable management and forecasting of energy efficacy.
- Establish the link between energy demand and accrued costs.
- Establish the feasibility of how the implementation of renewable sources can offset demand from the national grid, looking at treatment facilities at uMhlathuze municipality only.
- Recommend PV-MFC hybrid system as a viable technology that can produce a long lasting positive impact on energy demand, energy savings (conservation), and have a safe environmental impact.

The methodology in this paper thus outlines how adequately addressing the research questions in a manner that reflects the significance of the study that satisfies the aims and objectives of the paper can be achieved. The research questions are indicated.

3.4 Research Questions

- What impact does the country's economic and energy status have on municipal functions and its citizenry?
- What impact has the national grid and fossil-fuel (coal) based generation and supply have on municipalities, economic health of businesses in municipal jurisdictions, citizens and the environment?
- What impact does a poorly maintained municipal infrastructure such as a treatment plant have on energy consumption?
- What impact does having unrevised treatment processes with non-energy efficiency sensitive technologies and unreviewed policies have on energy consumption in conventional treatment plants (especially regarding energy conservation and efficiency)?
- What is the correlation or relationship between energy bills incurred and the costs of generating energy from fossil-fuel based sources?
- What are the gaps of implementing renewable energy systems or projects that enable generation of power from renewable energy sources as an alternative compared to fossil fuel generation for the municipality?

- What is the cost-benefit of using an PV-MFC hybrid system to generate electricity to power the wastewater treatment plant? In other words, what is the feasibility of employing the hybrid system to power treatment plants?
- What continuous improvement strategies can the municipality employ to enhance energy savings from the national grid and promote energy sustainability supply to the treatment plant?
- What modification can be conducted to improve performance and efficiency of a PV-MFC hybrid system using available self-replenishing renewable sources? And can such a self-sustaining system or technology be economically viable for local municipalities such as uMhlathuze local municipality?
- How would the system be feasible or be of positive impact for uMhlathuze municipality and for municipalities to invest in? Is decentralised renewable energy generation using municipalities as power generating hubs feasible for the South African energy market?
- What impact does legislation have in the energy sector, environment and design of a modified PV-MFC hybrid system?
- Can energy bills be reduced as a result of the implementation of the PV-MFC hybrid system and proposed incorporation of energy saving devices to the wastewater treatment plant in the medium-to-long term?
- How effective will the developed hybrid system be in replacing the conventional source of power from the national grid to power the wastewater treatment plant?
- What financing tools and/or agreements are in place, even if they are not effectively used? Can these be used by municipalities in effectively implementing renewable projects that ensure reliable and sustainable generation and supply that is all inclusive? Can both public and private sector partnerships be used to address energy related challenges (shortages, disruptions, etc.)?
- Can such a renewable system or project (i.e. the municipality generating energy and powering treatment plants) be self-sustaining, offering the municipality good revenue and the citizenry (including small-to-medium businesses and industries) affordable energy?

3.5 Significance of the Study

The significance of this study lies in its ability to address the above research questions and provide insight into how municipal institutions such as the City of uMhlathuze can use renewable energy as a feasible alternative source of generating electricity from available abundant resources to power heavy duty facilities such as municipal wastewater treatment plants. Although energy requirements vary from municipality to municipality depending on affordability or borrowing power of the municipality to willingly pursue energy generation from available renewable energy resources, an improved and reliable supply of energy can enhance the quality of life of citizens, promote reliable economic activities and delivery of services, and provide comfort or confidence of having a good security of supply. For uMhlathuze local municipality in the Richards Bay area, PV-MFC hybrid technology is recommended as a system that will aid the municipality in harvesting energy from reliable renewable sources, as the municipal area is imbued with abundant sunlight and can collect adequate quantities of biomass.

The feasibility of renewable energy supply for each municipality depends on the location of the municipality and

abundance of readily available renewable resources at the location under investigation or considered location. The municipality under study is situated in the industrialised town of Richards Bay, situated on the north-east coast of the KZN province, with a land coverage area of 123 325 hectares, and is estimated to have 110 503 households (using 2016 statistics), discharges an average of 25 000 m^3 of sewage to the effluent pipeline, accounting also for waste discharge from industrial and commercial activities. This means that biomass and sunlight are readily available abundant renewable sources that the city of uMhlathuze should explore for the generation of electricity.

Another significance that the paper highlights is that the benefit of using a hybrid system rather than a mono-system to harness renewable energy, is because then more than one readily available renewable energy source can be explored. That is, rather than municipalities investing in mono-systems or technologies, municipalities can invest in hybrid systems to circumvent the limiting factors of relying on one renewable energy source. The paper is of the view that the savings and added reliability in generating electricity from employing hybrid technology compared to mono based technology surpasses any cost consideration and anticipated risks.

Further significance is the importance of keeping infrastructure in acceptable operating conditions in order to aid efficiency and energy conservation, thus reducing energy wastage and high energy consumption resulting from poorly maintained infrastructure, and providing credible information and data regarding the impact of the hybrid technology on energy preservation and sustainability of supply.

4. RECOMMENDATION

4.1 Main Contributions to the Field of Study

According to Abd El-Aal (2005), a hybrid system is an economical alternative to large conventional power generating stand-alone mono-systems. The author states that PV-diesel generator hybrid systems are popularly used to power wastewater and water treatment plants, while diesel remains highly influenced by coal reserves and unpredictable markets. With this paper, the PV-Battery-MFC hybrid system has the diesel generator replaced by an MFC, and the fuel cell system is normally used as a back-up when the batteries reach a minimum allowable charging level and/or when the load (peak loads) exceeds the power produced by the PV system. Although Abd El-Aal (2005) reflects that MFCs have a slow response to the above mentioned conditions, a blended approach of generation is proposed, whereby PV and MFC based generation are continuous, with the PV system generating a larger proportion of the required energy. Thus, this paper reflects that all factors that seek to contribute to high and efficient generation of sustainable and reliable energy that enhance municipal confidence in securing security of supply, reduced energy bills in the medium-long term period, ensure rapid MFC response to electricity disruptions and delivery of multiple services to the community must be considered and modelled to ensure that high performance is achieved. The possibility of producing energy to meet demand, legislative requirements and objectives, reliable generation and supply standards and forecast based on population growth and industrial activities are some of the envisaged factors that must be observed and modelled.

5. CONCLUSIONS

This paper highlights the view that if questions and problem statements are adequately addressed, and kept at the core of finding lasting solutions, the feasibility studies are a crucial element to the successful planning for a HRES project, and adequate resources made available will see the implementation of HRES project an achievable reality. If feasibility studies are viewed as a time consuming exercise that require exorbitant funds that yield meaningless results, this will lead to

misdiagnosis of the problem at hand. Thus, outlining the problem statement and clearly indicating the above questions is necessary in the initial stage of a renewable energy project. Embarking on a comprehensive feasibility study on the use of PV-MFC hybrid system will enable the uMhlathuze municipality to conduct its business or provide for its current obligations with confidence and look forward to reliable future energy supply in a sustainable manner.

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